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REPORT
99-757

CENTAUR COST, SCHEDULE AND PERFORMANCE REVIEW

REPORT

BY THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

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LETTER OF SUBMITTAL

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC, August 7, 1986.

Hon. THOMAS P. O'NEILL, Jr.,
The Speaker, House of Representatives,
Washington, DC.

DEAR MR. SPEAKER: By direction of the Committee on Science and Technology, I submit herewith the report titled, "Centaur Cost, Schedule, and Performance Review", to the 99th Congress. This report is based on a staff investigation and hearings of the Subcommittee on Space Science and Applications.

Sincerely,

DON FUQUA, *Chairman.*

READEX FICHE best copy available

LETTER OF TRANSMITTAL

Hon. DON FUQUA,
Chairman, Committee on Science and Technology,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: In mid-1985 the Subcommittee on Space Science and Applications became aware that the Shuttle/Centaur program was going to experience a sizable cost overrun. To fully understand the scope and reasons for this overrun, the Subcommittee decided to conduct a thorough cost, schedule, and performance review of the program. This review began with a staff investigation and culminated in two days of hearings on May 21 and 23, 1985.

In the process of conducting this review, the Subcommittee discovered that in addition to specific mistakes that were made by NASA and contractor officials during the Shuttle/Centaur program, there were also several generic problems with NASA's contracting and management practices. A discussion of these problems and the Subcommittee's recommendations for how they should be resolved are contained in the accompanying report.

The recent cancellation of the Shuttle/Centaur program by Dr. James C. Fletcher makes it all the more imperative that NASA and the Congress study and learn from the mistakes that were made in this program so that these same mistakes are not repeated in future developmental efforts.

The accompanying report was prepared by Dr. Harry S. Dawson, Jr., of the Subcommittee staff. I commend the conclusions and recommendations to your attention.

BILL NELSON,
Chairman, Subcommittee on Space Science and Applications.

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Mr. FUQUA, from the Committee on Science and Technology, submitted the following

REPORT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The following is a summary of the major points that were obtained from the testimony received during the two days of hearings in May 1985 and the information collected during the detailed staff review that preceded the hearings.

1. Program officials at NASA and General Dynamics did not suspect that there would be an overrun on the Shuttle/Centaur program until after General Dynamics had expended one-half of the funds available in its contract with NASA. At that point, during the fourth quarter of 1984, NASA ordered that a detailed "cost-to-complete" analysis be conducted.

2. The Space Science and Applications Subcommittee held its authorization hearings in February of 1985, before the "cost-to-complete" analysis on the Shuttle/Centaur program had been finalized. At that time, NASA's Associate Administrator for Space Flight testified that tentative indications were that the overrun would be in the range of $30–$40 million.

3. At the more recent set of hearings in May, NASA officials expressed the belief that the Shuttle/Centaur program would overrun its budget by $95 to $110 million. The overrun in the development budget was projected to be about $60–$70 million (with the NASA share being about $40–$50 million and the DOD share, because of a previously agreed upon funding cap, being $20 million). Additionally, the cost of producing and launching the first two NASA vehicles and their associated flight support equipment was expected to be overrun by $35–$40 million.

4. The causes of the cost overrun were numerous and included the following:

The extensive use of overtime because of tight schedules and an inflexible launch date,

Unanticipated complexity of integrating the Centaur into the Space Shuttle,

Major labor disruptions due to cancellation and then reinitiation of the program soon after it began,

Two redesigns to correct for weight growth that exceeded prescribed limits,

A major redesign to correct for errors in engineering calculations,

A major redesign to accommodate the change of an overall redundancy specification for fluid handling systems,

Repair of a manufacturing defect in the hydrogen tank,

Difficulty in obtaining electronic component parts (e.g., integrated circuits) of adequate quality for use in space systems,

A strike by production workers,

Growth in production overhead rates, and

Underestimation of production tooling requirements.

5. Because of the necessity for a specific planetary alignment, the launch window for the first two spacecraft that were to be carried by the Shuttle/Centaur (i.e., Galileo and Ulysses) was only about two to three weeks long and occurs only every 13 months. A missed launch opportunity therefore, would result in a substantial and expensive delay in orbiting these two important spacecraft. Accordingly, the Shuttle/Centaur program officials at NASA assumed that the launch date could shift. Consequently, all design, development, test and material delivery problems experienced by the program were countered by the application of extensive overtime hours by the engineering, manufacturing, and testing workforces.

6. Each witness emphasized that a principal reason for the cost overrun was the unanticipated complexity involved in integrating the Centaur into a manned vehicle and ensuring that it would safely respond to all possible contingencies.

7. Within six months of beginning the Shuttle/Centaur development program in May of 1981, NASA decided to cancel the project. Then, following a mandate by the Congress, the program was restarted in July of 1982. This stop-start process resulted in the reassignment and loss of experienced Centaur personnel to other projects within General Dynamics.

8. At the outset of the Shuttle/Centaur Development program, a weight reserve of 200 pounds was established for the Centaur vehicles to be used for NASA's planetary launches. During the hearings, the Subcommittee received testimony that this weight margin was unusually low for a vehicle in development and thus provided insufficient flexibility to accommodate the normal growth in system weight that is typically experienced in a developmental program. Accordingly, as the program proceeded and the vehicle grew in weight to a point where system performance could have been compromised, it became necessary to redesign the flight equipment at considerable expense.

9. Through flight experience that had been gained with the Orbiter, in the summer of 1984 it was discovered that estimates of the

loads that would be experienced by some hardware elements had been underestimated. Specifically, General Dynamics found that the specifications that it had established for the large cryogenic valves in the Centaur emergency propellant dump system did not properly account for the true flight dynamics loads that would be generated during a Space Shuttle launch. It was also discovered that the loads that the Orbiter would transmit to the Centaur Integrated Support Structure (CISS) had been substantially underestimated by government and contract personnel in the Space Shuttle program. These engineering miscalculations resulted in an expensive redesign and the necessity to rebuild some hardware.

10. Initially, NASA had specified that all electronic and fluid components in the Shuttle/Centaur must be dual-fault tolerant. In the case of the fluid components on the CISS, however, this resulted in a very complex design which program officials determined could render the overall design less reliable than would be achieved with a reduced level of redundancy. Accordingly, NASA mandated that the fluid systems on the CISS be modified to be single-fault tolerant rather than dual-fault tolerant. This forced General Dynamics to scrap many existing fluid system and associated structural/avionic interface designs.

11. In March 1985, a leak was detected in the forward bulkhead of a Shuttle/Centaur hydrogen propellant tank that was undergoing testing. The cause of the leak was traced to a contour defect in the tank that was a result of metal shrinkage that occurred during the welding process used to produce the tank. If General Dynamics had conducted contour checks of its hardware as a part of its normal quality control procedures, this problem would have been detected before it resulted in a failure that damaged the hardware being tested. Finding an engineering solution to this program and implementing the necessary repairs to production hardware resulted in a two month schedule delay along with moderate impact on cost.

12. During the development and production of the avionics systems for the Shuttle/Centaur, General Dynamics experienced difficulty in obtaining electronic component parts of adequate quality for use in space systems. The firm solved the problem by buying available "military standard" electronic components and screening and testing them sufficiently to qualify them for a use on a manned space vehicle. However, General Dynamics experienced a higher than expected rejection rate in the electronic components that it tested. Consequently, it had to re-order and re-screen additional production lots of these components. This re-order/re-screen process had negative impacts on both the cost and schedule of the program.

13. Program officials from NASA and General Dynamics expressed optimism that though technical and schedule problems had been experienced and the remaining schedule continued to be very tight, both the Galileo and Ulysses spacecraft would be successfully launched in May 1986.

14. In the general area of contracting procedures, Mr. Boggs noted the following problem areas:

> NASA did not move fast enough to replace the "letter contract" (that was used to get the program underway quickly)

with a fully definitized contract (i.e., the letter contract issued in May of 1981 and reissued in July of 1982 was not replaced with a fully definitized contract until October 1983 for the development and production phase of the program, and August 1985 for the launch processing phase of the program),

The procurement regulations used by NASA and the Defense Department to purchase hardware (i.e., the Armed Services Procurement Regulations—ASPRs) have grown so cumbersome and unwieldy that they are not used in practice, and

DOD and NASA over-specify the characteristics of the hardware they buy.

15. During the hearings, several Members of the Subcommittee expressed strong concern over the government placing itself in a situation where it must pay for the mistakes that are made by contractors. The Committee understands that in many research and development efforts it is necessary for the government to shoulder most of the financial responsibility for the technological risks faced by its programs. However, contracting mechanisms are available that allow the government to carry most of the risk in a developmental program while still permitting the government to seriously penalize contractors for poor cost, schedule, or technical performance. For this particular development effort, NASA decided that because of the extreme schedule sensitivity of the Shuttle/Centaur program, it would not include any significant cost penalities for poor cost or technical performance in the contract to develop or produce the flight hardware.

B. CONCLUSIONS AND RECOMMENDATIONS

After analyzing all of the testimony and views that were offered at the hearings along with the data that was collected during the Subcommittee staff review prior to the hearings, the Committee has reached a number of conclusions and, where appropriate, made related recommendations.

1. Though the witnesses were optimistic that the overrun on the Shuttle/Centaur program should not exceed $110 million and that all necessary hardware would be available to support the launch of the Galileo and Ulysses spacecraft in May 1986, the Subcommittee concluded that there was still a reasonable doubt as to whether or not these expectations would be realized. There were many indications that the program had been brought under control, but the available schedule continued to be very tight with little room to accommodate additional problems should they arise. Thus, the Subcommittee's reservations.

2. The intent of the hearings was not to establish specifically who was at fault in causing the overrun in the Shuttle/Centaur program. On the other hand, from the testimony received during the hearings, the Committee is convinced that if blame were to be assigned, it would have to be allocated among many parties—including the prime contractor, NASA headquarters, two NASA field centers, and several other affiliated contractors or subcontractors.

3. The Committee believes that many of the problems experienced during the Shuttle-Centaur program serve to validate the conclusions and recommendations documented in the detailed

study of NASA project management practices conducted in 1980–81 by a study team under the direction of Dr. Donald P. Hearth. The Committee is convinced that if the recommendations in the Hearth Study were fully implemented, such problems would either not occur at all or not occur to the same extent. Some NASA program officials may argue that because of "the time-critical nature" of the Shuttle/Centaur program, there was not enough time to go through all of the preliminary steps called for in the Hearth Study recommendations. On the other hand, it is likely that one of the principal reasons why the Shuttle-Centaur program experienced such difficult problems is that sufficient time was not spent at the outset to lay adequate ground-work for the project.

The Committee recommends that NASA increase its efforts to ensure that all major programs within the agency fully adopt and apply the recommendations contained in the Hearth Study.

4. The Committee is particularly disturbed that:

NASA did not even suspect that there would be an overrun in the Shuttle/Centaur program until after more than one-half of the funds allocated to the project had been expended, and

No one affiliated with the program appears to have had an adequate appreciation for the magnitude of the task that would be involved in man-rating the Centaur upper stage and integrating it into the Space Shuttle.

Here again, the Committee believes that if the recommendations of the Hearth Study were to be fully adopted, such situations would be much less likely to occur.

5. The Committee is also concerned to find instances of a lack of obvious quality control measures such as the absence of contour checks for parts whose shape is critical to proper or safe functioning.

The Committee recommends that NASA take whatever steps are required to ensure that the quality control procedures used by all major contractors are fully adequate and acceptable.

6. It is clear that one of the overriding causes of the overrun on this program was the tight and inflexible schedule that had to be adhered to in order to be able to accomplish the planned planetary launches during the short launch window that was to be available in May of 1986. From witness testimony, it is equally clear that program officials thought that the cost of the 13-month delay that would result from missing this launch window would be substantially greater than the cost of the extensive overtime that would be required to resolve problems without having a negative impact on the schedule. However, in a submittal for the record, Mr. Beggs later estimated that the cost of a 13-month delay would be approximately $50 million. Therefore, it is possible that the government may have been able to save money by delaying the launch date rather than maintaining the schedule at all costs.

The Committee recommends that when NASA is faced with a program with a time-critical schedule, it conduct a thorough cost analysis to determine the full cost of a delay to the next available launch window. This analysis should be conducted early in the program and then, if a serious problem does occur, NASA should use the results of the analysis to determine if it would be cheaper to maintain the schedule or to let it slip.

7. Because of the time pressures on this program, NASA proceeded under a "letter contract" rather than waiting until a standard definitized contract could be negotiated. The Committee believes that though this contracting mechanism does allow the government to start a program quickly, it can produce a situaton where neither the government nor the contractor is motivated to complete negotiations on a definitized contract rapidly. A letter contract can also remove some incentive for the contractor to control his costs closely and can reduce the government's access to important information (e.g., detailed programmatic or financial plans may be unavailable from the contractor until a fully definitized contract has been negotiated).

The Committee recommends that NASA use extreme caution in issuing letter contracts. When such a contract type is deemed to be appropriate and in the government's best interest, NASA should exercise diligence in negotiating a definitized contract as quickly as possible.

8. The committee believes that the absence of cost penalties for poor cost or technical performance in a hardware development contract sends a message to the contractor "spend whatever you have to spend to achieve the schedule." Accordingly, the Committee believes that the exclusion of cost penalities for poor cost or technical performance from developmental contracts should be made very cautiously and that such exclusions should be permitted only in very special circumstances.

The Committee recommends that all future NASA contracts contain clauses that penalize contractors for exceeding their budget. In the future, should NASA believe that the special characteristics of a particular program mean that the use of such penalities would not be in the best interest of the government, before entering into a contract that does not contain penalities for cost overruns, the Administrator should notify the Committee of his intentions and the justification for such a contract.

9. The Committee notes that in recent years, many civil and military space programs have experienced difficulties in obtaining electronic components of adequate quality for use on space systems. This program appears to be pervasive throughout the entire aerospace industry, and historically has caused schedule and cost problems on many programs. Basically, the problem seems to stem from the fact that because spacecraft manufacturers normally produce flight hardware in very small quantities, electronic component suppliers are frequently unwilling to go the extra trouble and expense of producing components to standards that are more exacting than normal commercial or "military standard" specifications.

The Committee recommends that NASA create a task force of government and industry personnel to address the problem of obtaining adequate quality electronic component parts for space systems and formulate solutions to correct this problem. The Committee believes that better results will be achieved if the Defense Department participates in this task force, and if the industry representatives are drawn from both prime contractors and lower-tier suppliers of electronic components.

10. The Committee agrees with the NASA Administrator that the Armed Services Procurement Regulations used by NASA and

the Defense Department to purchase hardware from industry have grown overly cumbersome and unwieldly, and that they are in need of substantial modification.

The Committee recommends that NASA create a task force of government officials to determine what major changes should be made in its procurement regulations and procedures to make them more simple, understandable, efficient, and effective. It would be best if the Defense Department would participate in this task force, but if it does not, NASA should act unilaterally to review its own procurement regulations and procedures.

The Committee also requests that the above recommended task force conduct a thorough review of all procurement laws, regulations, and procedures and assess their impact on, or contribution to, the current problems that exist with the procurement system used by NASA and report back to the Committee with any recommendations.

11. The Committee believes that whenever problems arise, such as those that occurred in the Shuttle/Centaur program, NASA should use the experience as a major learning opportunity so that the likelihood of a recurrence of similar problems on future programs is reduced.

The Committee recommends that NASA compile a formal "lessons learned" report for the Shuttle/Centaur program and that this report be made widely available within the agency as well as to the Committee.

The Committee recommends that by December 1, 1986, NASA report to the Committee on how it is implementing each of the recommendations contained in this report.

I. Introduction

Before it was canceled by NASA Administrator James C. Fletcher in June 1986, the Shuttle/Centaur was a high-energy upper stage rocket that was being developed to launch major payloads from Space Shuttle's cargo bay. Prior to the Challenger accident, the first two flights of this upper stage were planned to occur within a ten-day period in May of 1986. One would have propelled the Galileo spacecraft toward Jupiter; the other would have placed the Ulysses spacecraft in a unique polar orbit around the Sun. Because of the particular planetary alignment that is required to conduct each of the missions, launch opportunities only arise every 13 months.

During the fiscal 1986 authorization hearings, NASA announced that there would be a cost overrun in the Shuttle/Centaur program.[1] Initially, NASA indicated that this overrun would be on the order of $30 to $40 million. Later, it began to appear that the actual overrun could be in excess of $100 million. Because of the magnitude of this problem and the importance of the Centaur to the time-critical launch of the Galileo and Ulysses spacecraft in May of 1986, the Subcommittee decided to conduct a thorough cost, schedule, and performance review of the Shuttle/Centaur program.

[1] *1986 NASA Authorization*, Volume II, Hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, Ninety-Ninth Congress, First Session, February and March 1985.

This Subcommittee review began with a staff investigation and culminated in two days of hearings on May 21 and 23, 1985.

In his opening statement, Chairman Bill Nelson (D-FL), stated:

> Mistakes have been made in this program. Our intent is to find out what they are, and whenever possible, determine what changes in NASA management policies and procedures could prevent their reoccurrence on other programs in the future.

Congressman Bob Walker, the Ranking Republican Member of the Subcommittee, added in his opening statement:

> Our purpose here today is not to point the finger of blame, nor to assess liability for a failed program. In fact, the Shuttle/Centaur program appears to be a success story in many ways. . . . The Committee on Science and Technology is concerned that there have been several problems with this program which could have been very serious. We want to examine those problems so that we, and NASA, will understand them better, and so that the lessons learned from the Shuttle/Centaur experience will become part of the institutional knowledge base within the agency.

II. Background

A. General

The Shuttle/Centaur was a large upper stage rocket that would have employed liquid oxygen and liquid hydrogen propellants to launch major NASA and DOD payloads from the Space Shuttle's cargo bay. The placement of a vehicle employing propellants that are as volatile and explosive as liquid oxygen and liquid hydrogen into the payload bay of the Space Shuttle posed numerous operational and safety challenges to the NASA/industry team developing the Shuttle/Centaur upper stage.

The Shuttle/Centaur was a derivative of the Centaur upper stage that was developed twenty years ago for use on expendable launch vehicles and has been utilized extensively since that time. In trying to develop the Shuttle/Centaur, NASA and the manufacturer attempted to retain intact as much of the original Centaur design as possible. A principal change from the design of the origional Centaur vehicle involved the widening of the liquid hydrogen tank from a diameter of 10 feet to a diameter of 14.2 feet. The liquid oxygen tank remained 10 feet in diameter, but was increased in length for the largest version of the Shuttle/Centaur.

The Shuttle/Centaur was being developed in two distinct models:

Centaur G-Prime—a 29-foot-long version being developed for NASA planetary payloads. This vehicle would have been able to accommodate spacecraft up to 30 feet long in the Space Shuttle cargo bay.

Centaur G—a 19.5-foot-long version being developed jointly for NASA and the Defense Department. This vehicle would have been able to accommodate spacecraft up to 40 feet long in the Space Shuttle cargo bay.

For each version of the Shuttle/Centaur, NASA was also developing a Centaur Integrated Support System (CISS) that would hold and support the vehicle and its payload within the Space Shuttle; and then, once in orbit, rotate the vehicle so that it could be deployed from the Shuttle. The CISS was also designed to quickly dump overboard all of the propellants contained within the Shuttle/Centaur should an emergency arise during launch.

B. EARLY HISTORY

In the Spring of 1981, the Committee on Science and Technology requested that NASA and DOD conduct a joint study of upper stage alternatives for use during the Shuttle era. The results of this joint study were transmitted to the Congress in early November 1981.[2] The study included a single recommendation:

> In order to satisfy the national mission requirement/needs of both the DOD and NASA, the Air Force should continue development and production of the IUS and NASA should develop the Centaur.

In anticipation of the results of this study, and the likely time-critical nature of the development program, NASA had initiated a "letter contract" [3] with General Dynamics for the design and development of the Shuttle/Centaur in May of 1981. This contract was subsequently updated in October of 1981. However, by the time that the Space Science and Applications Subcommittee held its 1983 authorization hearings in February of 1982, the Administration had reversed it decision and NASA testified that: "NASA does not, at this time, have any requirements for a short wide-body Centaur." [4] Instead, NASA indicated that it was going to rely solely on the IUS under development by the Air Force. This, in spite of the evidence that the Shuttle/Centaur would be less expensive than the IUS even though it would have substantially greater performance.

Later the same year (1982), the Congress, through the appropriations process, reversed the decision to terminate the development of the Shuttle/Centaur upper stage. The Committee on Science and Technology at that time opposed the appropriations action, although there were a number of Committee Members who voted in favor of the action.[5] In June of 1982, the letter contract with General Dynamics was modified to specify that two Centaur G-Prime vehicles were to be available and launched in May 1986—one car-

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[2] *Upper State Alternatives for the Shuttle Era*, a NASA/DOD Report to Congress, October, 1981.

[3] This is a quick-reaction contracting device that is sometimes used by the government to rapidly get a developmental or procurement effort underway when it is believed that taking the time to fully negotiate a contract before initiating a program would not be in the best interest of the government. Once a "letter contract" has been signed, it should ideally be replaced by a fully definitized contract as quickly as one can be negotiated.

[4] *1983 NASA Authorization*. Volume II, Hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, Ninety-Ninth Congress, Second Session, February and March 1982.

[5] On September 13, 1982, Congressmen Don Fuqua, Larry Winn, Ronnie Flippo, and Harold Hollenbeck issued a "Dear Colleague" letter on Committee stationery urging the House of Representatives to support an amendment to the HUD-Independent Agencies Appropriations Bill. This amendment would have deleted the $140 million included in the bill for Shuttle/Centaur procurement.

rying the Galileo spacecraft, the other carrying the International Solar Polar Mission (ISPM) spacecraft. The name of the ISPM spacecraft was later changed to Ulysses.[6]

The contract was again revised in November 1982 at which time it specified that in addition to the Centaur G-Prime the NASA needed for its planetary missions, a shorter, common vehicle (designated Centaur G) would be developed for DOD and NASA missions. The Air Force and NASA agreed to share equally the common development costs for the Centaur G vehicle. However, the Air Force "capped" its financial support for these common developmental costs at $150 million.

A final definitized contract for the development and production of the two Centaur G-Prime vehicles was not fully negotiated and signed until October 1983. Further, the definitized contract for the development and production of the two Centaur G vehicles for the Air Force was not fully negotiated and signed until February 1984. Additionally, the contract that covers the cost of processing and launching these four Shuttle/Centaur vehicles once they have been delivered to the Kennedy Space Center was not negotiated and signed until August 30, 1985. This latter contract was especially late given the fact that the first elements of Shuttle/Centaur hardware were shipped to the Kennedy Space Center in June of 1985 to begin processing for a launch in May 1986.

C. THE HEARTH STUDY OF NASA PROJECT MANAGEMENT [7]

In October of 1980, Dr. Alan Lovelace, Deputy Administrator of NASA, directed that Dr. Donald P. Hearth, Director of the Langley Research Center, create a study team of NASA personnel to: 1) identify generic factors that significantly influence the cost and schedule of NASA projects; and 2) recommend appropriate actions that NASA should take to minimize future problems.

Upon completion of the study, the participants were confident that if their recommendations were fully implemented, the occurrence of serious cost, schedule, or technical problems on major NASA programs would be greatly reduced. The recommendations from the Hearth Study that have particular relevance to the problems experienced in the Shuttle/Centaur development program are as follows:

Recommendation 2a—"NASA Management Instructions should incorporate the requirements for pre-project Analysis and Definition (Phases A and B)."

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[6] The Galileo and Ulysses programs began in 1978 and 1979, respectively. Both were originally intended for a launch from the Space Shuttle using the Inertial Upper Stage (IUS). Initially, Galileo was to be launched during early 1982 and Ulysses in early 1983. Because of budgetary and programmatic difficulties, however, these launch dates slipped to 1984, 1985, and finally 1986. During this period of time, it was determined that the Shuttle/Centaur would be a more appropriate upper stage for these spacecraft, requiring fewer launches (i.e., permitting the Galileo Orbiter and Galileo Probe to be more readily combined into a single spacecraft) and/or less complex orbital maneuvers to fully execute the missions.

[7] All the material in this section is drawn from the following document: *NASA Program Management and Procurement Procedures and Practices*, Hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, Ninety-Seventh Congress, First Session, June 24, 25, 1981.

Recommendation 2b—"Sufficient funding for definition should be included in NASA budgets . . . in order to insure thorough definition of future projects."

Recommendation 2c—"A formal 'Definition Review' should be conducted prior to inclusion of the project for implementation in NASA budget requests. . . . The Review Team will be composed of experienced project management, technical, and fiscal personnel drawn, on an ad-hoc basis, from organizations which will not participate in the implementation of the proposed project."

Recommendation 2d—"A 'Project Initiation Agreement' signed by the appropriate Program Association Administrator and Center Director(s), should be required before the proposed project is included in NASA's budget submittal. This brief document should outline the project objectives, management interfaces, acquisition strategy, schedules, budgetary levels, and other key ground rules established as a result of the Phase B definition and the 'Definition Review.'"

Recommendation 4—"NASA management should establish a policy that NASA Project Offices [for] all major NASA projects will have adequate visibility of contractor activities and resource expenditures in order to assess progress and problems and to develop the necessary understanding of the status of all project activities."

Recommendation 5—"After the implementing contractor is selected for a new NASA procurement, the first months of the contract activity should be funded at a low level and be directed at developing an early NASA/contractor understanding of the project's scope and interfaces. This should be completed prior to the commitment of major expenditures, and should include the following:

Maturing the Phase B baseline design,

Developing system specifications including definition of major interfaces,

Providing a risk assessment and identification of critical technologies,

Providing detailed implementation plans and work packages,

Providing detailed cost to complete."

Recommendation 7—"NASA management should establish a policy that all major NASA projects will include adequate reserves. These reserves will be to cover potential program adjustments, defined as 'APA', and potential technical and schedule problems, defined as 'contingency'. . . both the APA and the contingency should be re-evaluated after 'the early understanding between NASA and the implementing contractor' (Recommendaton 5). In addition, projects should include technical and schedule margins, where possible."

III. Witnesses

During the two days of hearings, the Subcommittee heard testimony from the contractor that was developing the Shuttle/Centaur hardware as well as the NASA officials who were overseeing the program.

The principal witness on May 21 was the NASA Administrator, James M. Beggs. He was accompanied by Jesse W. Moore, NASA's Associate Administrator for the Office of Space Flight; Andrew J. Stofan, the Director of NASA's Lewis Research Center in Cleve-

land, Ohio where responsibility for the Shuttle/Centaur program lies; and Larry Ross, the Director of Space Flight Systems at the Lewis Research Center.

In his testimony, Mr. Beggs summarized the overrun situation as follows:

> . . . the development of both vehicle configurations and production of the first two NASA vehicles will require additional funding of $100–$110 million. The development portion is $60–$70 million, of which $20 million will be funded by the DOD. The $20 million for the DOD is the amount over NASA's 1986 budget estimates that will take them to an agreed-to cap of $150 million for their share of development costs. The increase in the NASA operations for Galileo and Ulysses is approximately $35–$40 million. The DOD is still addressing their position on the additional funding required for their first two vehicles.

In concluding, he went on to say:

> In summary, as we look at the STS/Centaur program progress over the past three years, we have moved forward to meet the challenge of launching two planetary missions back to back in the May/June 1986 timeframe. Our schedule, as it has been from the very start, remains very tight but doable. We have experienced some technical and schedule problems which require more funding than we planned at the outset, but we are confident that we will successfully launch two planetary missions in May 1986. We are proceeding with the development of the common NASA/DOD Centaur stage and will take the necessary programmatic actions required to assure its successful development for both essential national security and NASA missions.

On May 23, the primary witness was Dr. Alan Lovelace, Corporate Vice President and General Manager of the Space Systems Division of General Dynamics. Dr. Lovelace was accompanied by Martin K. Winkler, Director of the Shuttle/Centaur program at General Dynamics.

Dr. Lovelace summarized his testimony as follows:

> . . . we have faced what we consider a normal set of problems for a highly constrained development program with many technical interfaces. To date, we have satisfactorily resolved them all. In the process, we have exceeded our cost targets by approximately 20 percent. While we do not take this lightly, we do take great pride in the accomplishments to date of this extremely challenging program. We still feel confident in successfully flying the Galileo and Ulysses missions next year and look forward to a Shuttle/Centaur program that will be as long in duration, and as successful, as our Atlas/Centaur program.

IV. Major Issues

A. The Cost Overrun

The review of the Shuttle/Centaur program conducted by the Subcommittee staff prior to the hearings reconstructed the following chronology of cost estimates as they evolved throughout the program.

NASA's official cost projections for the Shuttle/Centaur program compiled at at the end of 1982 estimated that:

The research and development cost for the G and G-Prime vehicles would total $383 million, and

The production and operations cost for the two NASA G-Prime vehicles would total $196 million.

By the time that the NASA FY 1986 budget was compiled during the summer of 1984, these estimates had been lowered slightly to $379 million and $194 million, respectively.

By August of 1984, General Dynamics had expended one-half of the funds available in its contract with NASA, and yet there was still no concern within NASA or the contactor that the program would exceed its budget. The program had experienced some problems, but everyone affiliated with the project believed that the cost impact of these problems could be handled by the contingency reserves that were available within the overall program budget.

By the fourth quarter of 1984, General Dynamics began to suspect that there would be an overrun in the program. The company informed NASA of this fact, to which Nasa responded by ordering that a detailed "cost-to-complete" analysis be conducted. When the Subcommittee held its authorization hearings in February of 1985, the "cost-to-complete" analysis had not yet been fully completed. However, when pressed for an estimate of the likely size of the overrun, NASA's Associate Administrator for Space Flight responded that tentative indications were that it should be in the range of $30-$40 million. About a month later, NASA was embarrassed to learn that the overrun would likely be in the vicinity of $100-$110 million.

Mr. Beggs testified that it appeared that the developmental cost of the program would be $60-$70 million more than had been budgeted (with the NASA share of the overrun equalling $40–$50 million, and the DOD share, because of a previously agreed upon funding cap, equalling $20 million). In addition, Mr. Beggs indicated that the production and operations cost of the NASA part of the program budget (i.e., for the first two Centaur G-Prime vehicles) appeared that it would overrun by about $35–$40 million. Thus, the total overrun above the NASA FY 1986 budget projection would likely be in the range of $95 million to $110 million (an overrun of about 20 percent). Because of contractual negotiations that were ongoing between NASA and General Dynamics, NASA was unwilling during the hearings to make projections of the likely purchase price of future units of Centaur G-Prime flight hardware.

During the hearing Dr. Lovelace observed that these overrun figures contain $33 million in reserves in the development contract to cover future problems and contingencies. There were also additional reserves in the production and operations contract. He noted,

therefore, that there was some possibility that the actual overrun at the completion of the contract could be less than projected.

B. REASONS FOR THE COST OVERRUN

During the formal hearings and the detailed staff review that preceded them, a number of reasons for the cost overrun became apparent. Each of these reasons were discussed during the hearings, and were investigated in much greater depth during the staff review. The information presented here is drawn from both the hearings and the more detailed staff review.

1. The extensive use of overtime because of tight schedules and an inflexible launch date

The launch window that was available for the spacecraft which were to be carried by the two NASA Centaur G-Pime vehicles was only about two to three weeks long and occurs only every 13 months. The NASA officials affiliated with this program testified that they always believed that the costs that would be incurred by the government would be substantially greater if this planetary launch window were missed than if the schedule were maintained through the extensive use of overtime labor hours by contractor personnel.[8]

Accordingly, NASA officials always assumed that the launch date could not shift. Consequently, all design, development, test and material delivery problems experienced by the program had to be countered by the application of overtime hours by the engineering, manufacturing, and testing workforces. For the Shuttle/Centaur program, these overtime hours have been extensive.

2. Unanticipated complexity of integrating the Centaur into the Space Shuttle

Each of the witnesses and the other program officials interviewed by the Subcommittee staff emphasized that a principal reason for the cost overrun was that no one had anticipated how difficult a task would be involved in integrating the non-man-rated Centaur into a manned vehicle, and ensuring that it would safely respond to all possible contingencies.

In the past several years, the Subcommittee has heard several satellite owners testify that they had greatly underestimated the task of integrating their spacecraft onto the Space Shuttle. They indicated that their experience in integrating payloads on expendable launch vehicles did not prepare them for the magnitude of the effort that was required to transition an initial model of one of their spacecraft onto the Shuttle. The principal difference with the Space Shuttle is that it is a manned vehicle, so the integration process includes a thorough assessment to ensure that all payloads and their affiliated upper stages meet the high safety standards associated with manned space flight as well as other standards for being carried within the Shuttle's cargo bay. This process is especially complicated because assurance must be gained that a pay-

[8] However, in material supplied for the record, Mr. Beggs later estimated that the cost of a 13-month delay in launching these spacecraft would equal about $50 million.

load or upper stage is capable of accommodating all possible abort or failure modes that can arise during a Space Shuttle launch.

Given this consistent testimony on the difficulty of integrating flight hardware into the Shuttle, together with the lack of recent experience in manned space systems by the project teams at General Dynamics and the Lewis Research Center, it may be understandable that they would underestimate the task of integrating the Centaur upper stage into the Space Shuttle. However, it is not clear how the officials involved in the program at NASA headquarters and the Johnson Space Center in Houston could make such an error.

In his opening statement on May 21, Mr. Walker stated that:

> The Committee views this failure [to accurately predict the effort that would be required to integrate the Centaur into the Space Shuttle] with considerable alarm since the potential problems NASA might face in this area were pointed out repeatedly by this Committee in the past. We fully support the safety requirements proposed upon Shuttle payloads and agree that they are necessary to protect the crew. We cannot understand why NASA as an institution did not comprehend how difficult the integration would be and plan accordingly.

In his questioning of Dr. Lovelace, Chairman Nelson expressed similar sentiments.

> . . . . I don't fault General Dynamics nearly so much as I do NASA for not being heads up on that, because NASA is the one that had the experience with the manned systems and what it took to integrate them.

In discussing the lessons that have been learned from this overrun, Mr. Stofan suggested that if NASA had programatically treated the Centaur as an integral part of the Space Shuttle rather than merely another payload, the complexity of the integration task may have been recognized sooner and more readily handled. In his testimony, Dr. Lovelace said that he had initially thought that handling a complex system like the Centaur as an integral part of the Space Shuttle, rather than as a payload, would have moderated some of the problems that had been faced by this program. However, upon further reflection, he had concluded that for a project with the schedule constraints of the Shuttle/Centaur program, he was not sure that it would really make much, if any, difference.

3. Major labor disruptions due to cancellation and then reinitiation of the program soon after it began

Six months after NASA initiated the Shuttle/Centaur program, the agency began to reverse its decision to develop this upper stage. NASA issued an order to phase-down the program in November of 1981 and then formally cancelled the project in April 1982.

In July of 1982, as part of an Urgent Supplemental Appropriations bill, the Congress mandated that the Shuttle/Centaur program be restarted. In compliance with this congressional direction, NASA issued contracts that same month to restart the Shuttle/Centaur development program.

Several witnesses pointed to this stop-start cycle at the outset of the program as an obvious cause for some of the problems that had been experience. Dr. Lovelace observed that stops and starts in the front end of a program tend to result in a high state of concurrency, in which a firm finds itself designing, manufacturing, and conducting safety reviews simultaneously. He further indicated, that with such a high degree of concurrency, when problems do arise, their effect on the program is amplified by 5 to 10 times.[9]

A potentially more important impact of these stops and starts is the effect that they can have on the available labor force. When a program is cut back or cancelled, the manufacturer must reassign the personnel working on the project to other activities. If a program is later restarted, it is not uncommon that key personnel who were with the project originally cannot be spared from their current duties for reassignment to the restarted project. Accordingly, they may be replaced by individuals with less experience with the program.

In the case of General Dynamics, when the Shuttle/Centaur phase-down and cancellation orders were issued by NASA, many key personnel were assigned to the firm's Cruise Missile program. When the Shuttle/Centaur project was restarted, some of these key people with years of experience in the company's Atlas-Centaur and Titan-Centaur programs were not reassigned back onto the Shuttle/Centaur project. This loss of key experienced personnel had a major impact on the program.

4. Two redesigns to correct for weight growth that exceeded prescribed limits

At the outset of the development program, a weight reserve of 200 pounds was established for the Centaur G-Prime vehicle. It is standard practice to establish a weight margin in any spacecraft or upper stage developmental effort. However, Dr. Lovelace testified that the weight reserve that was established for this program was unusually low. In fact, he said that it: "Would be low for a mature launch vehicle, no less one in development." [10]

As the developmental program proceeded, the vehicle began to grow in weight. During two periods of time, the summer of 1983 and the spring of 1984, the weight had grown to a point that system performance would have been marginal. In each instance, to correct this problem the weight of the vehicle was reduced by about 200 pounds by redesigning a large number of individual components, some of which had already completed their design phase or (in 1984) had already been fabricated.

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[9] On the other hand, it should be mentioned that when the Shuttle/Cenaur program was started in May 1981, the planned launch date for both the Galileo and Ulysses spacecraft was April 1985. When the program was restarted in July 1982, the launch date for these spacecraft was set for May 1986, so the time available to accomplish the development program remained approximately the same as when the project was initiated the first time. To the extent that concurrency did occur during this program, it was more likely a result of the tight schedules that had always existed to support an inflexible launch window.

[10] On other hand, testimony by NASA officials at the outset of the Shuttle/Centaur program indicates that, because of the twenty years of experience with the original Centaur upper stage, they *did* view the launch vehicle to be "mature". See: *1984 NASA Authorization*, Volume 11, Hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, Ninety-Eighth Congress, First Session, February and March 1983.

Dr. Lovelace observed:

> These redesigns were considered prudent, although costly at the time. Other options, including release of additional Shuttle lift commitment from reserves or the lowering of the Shuttle parking orbit, were properly rejected at that time and reserved for future contingencies.

5. A major redesign to correct for errors in engineering calculations

Through flight experience that had been gained with the Orbiter, in the summer of 1984 it was discovered that estimates of the loads that would be experienced by some hardware elements had been underestimated. Specifically, General Dynamics found that the specifications that it had established for the large cryogenic fluid valves in the Centaur emergency propellant dump system did not properly account for the true flight dynamics loads that would be generated during a Space Shuttle launch. Also, Johnson Space Center and Rockwell International discovered that the mechanical loads that the Orbiter might impose at the interface between the Orbiter and the Centaur Integrated Support Structure (CISS) could be substantially larger than originally predicted. In fact, possible loading conditions on certain fluid components were found to be seven times larger than originally projected.

This resulted in a redesign of the large propellant valves in the CISS and the interface connections between the Orbiter and the CISS. The CISS was then totally redesigned to reduce its weight in order to compensate for the increase in the weight of the newly redesigned components.

Unfortunately, the need to redesign the large cryogenic valves in the CISS was not recognized until after the valves had already been ordered and built (at a cost of about $10 million). This redesign error required that a replacement set of valves be produced at a cost of an additional $10 million. It also resulted in a three month schedule delay.

6. A major redesign to accommodate the change of an overall redundancy specification for fluid handling systems

Initially, NASA had mandated that all electronic and fluid components of the Shuttle-Centaur be dual-fault tolerant. This means that even if two redundant components should fail in any way, the system would still function properly. In the case of the fluid components on the CISS, this resulted in a very complex design.

During a Preliminary Design Review conducted in the summer of 1983, the question arose whether the reliability of the CISS was in fact being compromised by the dual-fault tolerance requirement. The concern was that the added complexity required to achieve dual-fault tolerance in the fluid systems was likely to make the overall design less reliable than would be achieved with a reduced level of redundancy. Accordingly, a senior NASA team headed by the Johnson Space Center was tasked with conducting a thorough safety and reliability analysis of the CISS. As a result of this review, the NASA team recommended that the fluid system on the CISS be modified to be single-fault tolerant rather than dual-fault tolerant.

Dr. Lovelace testified that: "This dramatically simplified many of the CISS subsystem designs, but caused General Dynamics to scrap many existing fluid system and associated structural/avionic interface designs."

7. Repair of a manufacturing defect in the hydrogen tank

In March of 1985, a hydrogen leak was detected in the forward bulkhead of a test tank that was undergoing cryogenic cycling tests at General Dynamics. It was discovered that spot welds had cracked because the contour of the bulkhead of the tank had not been produced to design specifications. This manufacturing error had resulted in a doubling of the stresses experienced by the welds that hold the bulkhead together, and as a result, many of the welds failed. The cause of the contour error was unanticipated shrinkage that occurred during the welding phase of fabrication.

Dr. Lovelace testified that this situation should have been anticipated but unfortunately was not. Also, if General Dynamics had conducted form or contour checks after producing its hardware, the problem could have been discovered before resulting in a failure that damaged the hardware being tested.

A repair involving the placement of additional sheet metal over the weak area of the hydrogen tank bulkhead was designed and implemented. The acceptability and flight worthiness of this design change was verified through rigorous testing.

The solution of this problem and the repair of the test tank and the two Centaur G-Prime flight tanks resulted in a two month schedule delay along with a moderate cost impact and a small increase in vehicle weight.

8. Difficulty in obtaining electronic component parts of adequate quality for use in space systems

For many years, manufacturers of space hardware have had difficulty in obtaining electronic component parts that are designed and qualification tested to the demanding specifications required for space hardware. Because of the low production volumes involved, many electronic component suppliers refuse to produce to specifications in excess of "military standards". When a spacecraft manufacturer needs a "space qualified" part, the manufacturer frequently must buy "military standard" parts and then thoroughly screen them until finding those that can meet the more demanding space standards. Unfortunately, the "yield" that is obtained from this process is highly variable and essentially unpredictable (e.g., the manfacturer may have to screen 10, 100, 1000, or even more "military standard" electronic components to find a single unit that can meet the reliability standards for spacecraft components).

During the development and production of the avionics systems for the Shuttle/Centaur, General Dynamics experienced this common aerospace industry problem. The firm solved the problem in the normal way, buying available electroinc components and screening and teting them sufficiently to qualify them for use on a manned space vehicle. However, General Dynamics experienced a higher than expected rejection rate in the electronic components that it tested. Consequently, it has to re-order and re-screen addi-

tional production lots of these components. This re-order/re-screen process had negative impacts on both cost and schedule.

An additional problem that was faced by General Dynamics stemmed from the age of the designs of many of the Centaur avionics systems. Because of the proven nature and high reliability of the electronic sytem designs that have been flying on the standard Centaur for many years, both the firm and NASA wanted to utilize these designs to the greatest extent possible. However, some of these designs have reached the point that they are now 25 years old. It can be difficult to find manufacturers interested in continuing to build such old technology hardware in the low quantities required for programs like Centaur and Shuttle/Centaur. Accordingly, the design of some components had to be modified in order to find someone willing to produce them. The number of avionics components requiring redesign had not been accurately anticipated.

For the flight articles that had been scheduled to be launched in the coming year, these problems had been overcome. In fact, in response to a question from Mr. Nelson, Dr. Lovelace stated his belief that General Dynamics even had an adequate set of *spare* avionics hardware available to fully support the two Shuttle/Centaur launches that had been planned for the coming year. These spares could be required if a unit of flight hardware were to fail or evidence some anomalies during pre-flight checkouts.

9. A strike by production workers

In July 1984, the Convair Division of General Dynamics was faced with a strike by over 4200 members of the International Association of Machinists—the first such strike in 20 years. Although the strike lasted only two weeks, the schedule-critical Centaur G-Prime program was set back three to four weeks because of pre-strike work slowdowns and the necessity to conduct detailed post-strike inspections of flight hardware quality. This necessitated more overtime and, thus, more cost.

10. Growth in production overhead rates

During this program, General Dynamics experienced some unplanned growth in overhead rates at the Convair Division. Dr. Lovelace explained that during 1984, the business base of direct labor at Convair was shrinking faster than the base of indirect or support labor. Accordingly, the ratio of these two labor bases (a primary determinant of the overhead rate) began to grow. During the hearing Dr. Lovelace estimated that the total budgetary effect of this growth in division overhead rates was about $4.7 million. In a subsequent written statement for the record, Dr. Lovelace indicated that $2.9 million of these funds were of a category ("New Business Funds Over Ceiling Rate") that would be billed to the government. A large part of the remaining cost growth was due to difference in the accounting treatment of wage increases granted after the Shuttle/Centaur contract was negotiated. Wage increases recently negotiated with the unions at General Dynamics took the form of lump sum wage payments which were treated as an overhead cost rather than a direct labor cost.

When questioned as to whether or not there were any similarities between the overruns that were being experienced on the Shut-

tle/Centaur program and the improper charges that General Dynamics had assigned to certain DOD contracts, Dr. Lovelace stated:

> To the best of my knowledge, Mr. Chairman, I have checked with our corporate people . . . there is no reflection of any of the alleged improprieties in General Dynamics on this particular contract or overrun.

Mr. Nelson went on to query:

> . . . you are telling us that you are going to make sure there are no improper charges that are assessed against this contract?

To which Dr. Lovelace responded:

> "Yes sir."

11. Underestimation of production tooling requirements

Finally, during the subcommittee staff review that was conducted prior to the formal hearings, General Dynamics indicated that it had underestimated the number of production tools that would be required to support the program. The purchase and/or fabrication of the unanticipated production tools also added to program cost.

C. OTHER RELATED ISSUES

In addition to cost related issues, several other important aspects of the Shuttle/Centaur program were addressed during the hearings. These are discussed below.

1. Schedule status

Dr. Lovelace testified that there has always beeen a high level of schedule risk in the Centaur G-Prime program. He observed that:

> Launching of two Shuttles, with two Centaurs, and two different interplanetary spacecraft, from two launch pads, within a 20-day period is a feat never before accomplished.

Mr. Beggs summarized:

> Our schedule, as it has been from the very start, remains very tight, but we believe doable . . . we are confident that we will successfuly launch two planetary missions in May 1986.

Later he went on to explain:

> . . . in my long experience with programs—when you are in [a] development activity, you look for evidence of convergence, which is to say, are the problems getting smaller, or are they getting larger? In this case, I think the problems are getting smaller.

On the other hand, Dr. Lovelace admitted that the program continued to run slightly behind schedule. Therefore, it appeared that the program still faced a considerable degree of schedule risk.

2. Performance status

Jesse Moore testified that it appeared that the Centaur G (the shorter of the two types of Centaur vehicles under development)

was going to have performance capabilities within the established specifications.

The Centaur G-Prime vehicle, on the other hand, was experiencing some performance-related problems. Specifically, the vehicle was having some difficulty in complying with established weight margins. At the time of the hearing, the vehicle being produced for the Ulysses mission was still in compliance with the establishment weight margin. However, the vehicle that was being produced for the more demanding Galileo mission was exceeding its weight margin by about 42 pounds. During the pre-hearing program reviews, the Subcommittee staff was told that this vehicle could likely end up being about 150 pounds heavier than originally desired. On the other hand, it appeared that there were still sufficient weight margins elsewhere in the overall program (e.g., in Orbiter performance) so that all mission-related objectives should still have been achievable.

3. Government contracting practices

One of the subjects that kept arising during the hearings was the general topic of government contracting procedures. Mr. Beggs reminisced that 20 years ago the Armed Services Procurement Regulations (ASPRs)—used by the Defense Department and NASA to purchase everything that they buy from industry—were contained in three or four volumes. By contrast, he observed that today these procurement regulations comprise a set of volumes several feet thick. Furthermore, Mr. Beggs noted, they are so cumbersome that nobody reads them. He musingly suggested:

> . . . maybe we ought to move back somewhere towards that original contract with the Wright Brothers, which was written on one side of one sheet of paper. We probably can't get all the way back there, but we can certainly [move] a long ways back from where we are. . . . I think that part of our problem is that we are way overspecified for what we are buying. And both the DOD and NASA are guilty of that sin.

He concluded by stating that:

> . . . we ought to accelerate that, and I think anything that the Congress can do to say look, if anything that we did in the past in imposing on you either legal or other requirements is making you manage in excruciating detail, that is inhibiting the contractor from doing his job, tell us and we will back away from that. That would be helpful.

Another focus of discussion at the hearings was the use of letter contracts to initially get the Shuttle/Centaur development program underway. Mr. Beggs testified:

> . . . if I had my druthers, I would never issue a letter contract. . . . A letter contract immediately takes pressure off both sides to complete negotiations of a definitive contract. It takes the pressure off the contractor, he is covered, and he knows that as he accumulates costs, he can bring those costs in and put [them] on the table as actuals and negotiate from that point. It takes the pressure off of

> the agency, because we know the work is going forward, even though we don't have a definitive contract. And we say, "Well, we are meeting our schedules, therefore we can take the necessary time in order to ensure that this negotiation is exactly right."
>
> In my long experience in industry, I have been party to, and I am not proud of it, but I have been party to letter contracts which go on to the point where the hardware is delivered. Then everything is actual. And that is very bad. Because it takes all of the risk out of the job, and there is no incentive left for either party to have done anything differently in order to either minimize costs or ensure delivery.

Mr. Beggs went on to explain that letter contracts are normally used on programs where schedule is the critical pacing consideration. Accordingly, when asked by Mr. Nelson: "Now, looking back on it and knowing what we all know now, given the same time constraints and so forth, would you sign another letter contract?" Mr. Beggs responded:

> Yes, I would sign another letter contract. In retrospect, we probably would put more pressure on to have definitized that contract. Although I can't say that the definitization process really had any real impact on the problems that we are facing today.

During the final day of the hearings, several Members of the Subcommittee noted that, in the future, NASA is going to have to make major changes in the way it conducts its contractual business:

Chairman Nelson said:

> I think that this new era of limitation is going to require us . . . to perhaps put a limit on the increase that a contractor could experience before having to come back to the authorizing committee in Congress . . . [to] allow that particular limit to be pierced.

Mr. Smith agreed, saying

> Why should the taxpayers be stuck for errors, and not improprieties in this particular case, but for errors or misjudgments or inaccuracies on your [General Dynamics'] part? What is the sense of having a contract?

Addressing Dr. Lovelace, Mr. Barton stated:

> If you take one thing back to corporate headquarters, take the message back that this Congress . . . is not going to be business as usual on the defense budget. It is not going to be business as usual in the overall budget. We really are going to hold the General Dynamics of the world to task.

Mr. Monson indicated:

> I think it points out that we in Congress need to do what we can do . . . [make] the changes that are required.

Later, with respect to another point, Mr. Walker agreed, saying:

> If it is a procedural problem . . . then we had better get about the business of changing the procedure.

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